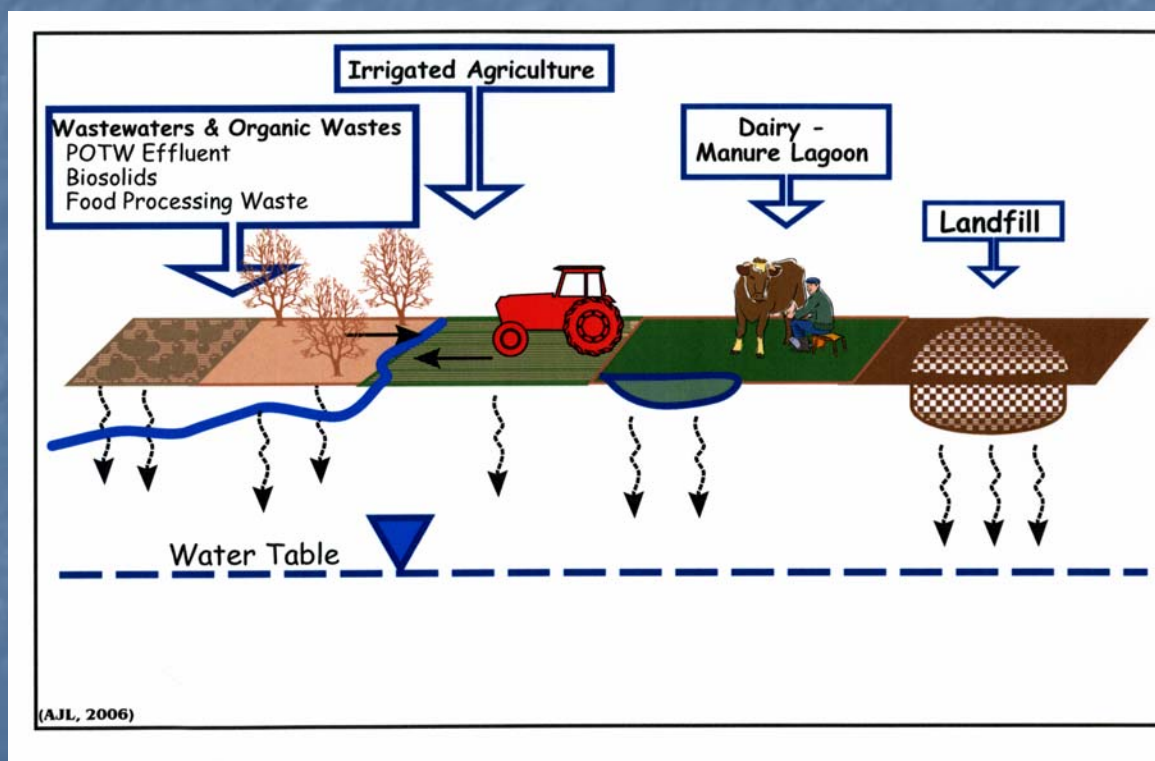


Groundwater Quality Protection Issues

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Groundwater Quality Protection Issues Report, December 2006 by G. Fred Lee & Anne Jones-Lee

- 80-page Report (+ Appendices)
- Discusses Deficiencies in Regulation of Land Surface Activities That Can Lead to Groundwater Pollution
- Provides References to Sources of Additional Information
- Available at:
[http://www.members.aol.com/annejlee/
GWProtectionIssues.pdf](http://www.members.aol.com/annejlee/GWProtectionIssues.pdf)

Background to Developing Report

- Dr. G. Fred Lee Has Been Involved in Evaluating Groundwater Pollution by Various Sources since 1960
 - In Central Valley since 1989
- This Report presents –
 - Summary of Issues Encountered related to Groundwater Pollution
 - Emphasis on Pollution Situations in California Central Valley

California Regulatory Requirements

- Porter-Cologne Water Quality Control Act (SWRCB 2006), Division 7, Chapter 1, section 13000, states, *“The Legislature finds and declares that the people of the state have a primary interest in the conservation, control, and utilization of the water resources of the state, and that the quality of all the waters of the state shall be protected for use and enjoyment by the people of the state.”*

http://www.swrcb.ca.gov/water_laws/docs/portercologne.pdf

Regulatory Requirements (cont'd)

- Porter-Cologne Chapter 2, section 13050, paragraph (e) defines “waters of the state” as “*any water, surface or underground, including saline waters, within the boundaries of the state.*”
- *The CVRWQCB (1998) Basin Plan, in Chapter III Water Quality Objectives, on page III-10.00 under the section entitled, “Water Quality Objectives for Ground Waters,” states, “Ground waters shall not contain chemical constituents in concentrations that adversely affect beneficial uses.”*

US Geological Survey Groundwater Quality Studies

- USGS National Water-Quality Assessment Program Examined Relationship between Land Use & Groundwater Quality
 - Studies Have Shown That Land-Use Activities in Urban & Agricultural Areas are Causing Groundwater Pollution
 - Of Particular Concern:
 - Fertilizers/Nutrients/Nitrate
 - Salinity
 - Solvents (VOCs)
 - Pesticides/Herbicides
- DWR Groundwater Program Also Reported Widespread Groundwater Pollution in Central Valley

Natural Pollution of Groundwaters

- California Comparative Risk Project Found as One of Most Significant Threats to Human Health in Some Areas of California:
 - Pollution of Groundwaters by Naturally Occurring **Arsenic & Radon**

Irrigated Agriculture

- Among Most Significant Causes of Groundwater Pollution in California
 - Nitrate & Salts
 - Pesticides
 - Although DPR Is Improving Regulation of Pesticides that Have Potential to Pollute Groundwaters
- Groundwater Pollution by Irrigated Agriculture can be Reduced, but Not Eliminated

“DILEMMA: MANAGING GROUND WATER QUALITY AND IRRIGATED AGRICULTURE”

JOHN LETEY

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University of California, Riverside, CA*

Proceedings of the 19th Biennial Conference on Ground Water, J. J. DeVries, J. Woled, editors. Water Resources Center Report No. 84, University of California, Davis, pp. 97-104, December (1994)

- Provides Good Discussion of Issues of Groundwater Pollution from Irrigated Agriculture
 - Appended to Report

Pesticide Pollution of Groundwater

- DPR Regulations Restrict Regulation of Pesticides that Have Not Been Proven to Cause Groundwater Pollution
- DPR Now Evaluating Potential for a New Pesticide to Cause Groundwater Pollution through Probabilistic Pesticide Transport Modeling of Expected Transport in Aquifer Systems
- Use this Information in Registration of a Pesticide
 - Can Lead to Restrictions in Use of Pesticides that Can Cause Groundwater Pollution

Nitrate Pollution of Groundwater

- Sources of Nitrate [All Forms of N (Ammonia, Nitrite, Organic N) Can Be Converted to Nitrate]
 - Nitrogen Fertilizers – Organic & Inorganic
 - Animal wastes – Feedlots, Dairies etc.
 - Food Processing Wastes & Other Organic Wastes
 - Domestic Wastewaters – From Land Application of POTW Effluents
 - Application of Sewage Sludge – Biosolids at Agronomic Rates Can Lead to Pollution of Surface Water & Groundwater
 - Septic Tank Disposal Systems

Nitrate Pollution (cont'd)

- Application of Nitrogen Fertilizers & Wastes at Agronomic Rates Does Not Prevent Pollution of Groundwater by Nitrate
 - Cannot Reliably Predict Rate of Conversion of Organic N Compounds to Ammonia & Nitrate
 - Carry-Over of N from One Year to Next
 - Contributes to N loading and failure of agronomic application rates to protect groundwater from pollution by nitrate

Nitrate Groundwater Pollution Hazard Index

- Developed for Irrigated Agriculture in the Southwest.
- *“To provide information for farmers to voluntarily target resources for management practices that will yield the greatest level of reduced nitrogen contamination potential for groundwater by identifying the fields of highest intrinsic vulnerability.”*
- *“How it Works: The index works with an overlay of soil, crop, and irrigation information. Based on the three components, an overall potential hazard number is assigned and management practices are suggested where necessary.”*
- Available at:
http://lib.berkeley.edu/WRCA/WRC/wqp_hazard.html.

Groundwater Monitoring Issues

- Ideal: Monitor Groundwater Near Source to Detect Potential Pollution Before Major Pollution Occurs
- Vadose Zone (Unsaturated Part of Aquifer) Monitoring
 - Early Warning of Potential Pollution
 - Must Be Done Correctly
 - Can Indicate Whether Intercepted Percolating Water Contains High Concentrations of Potential Pollutants
 - Data Interpretation: Must Also Know Water Flux to Determine Mass Flux Rate of Pollutant(s)
 - Not Easily Accomplished – See Report for Guidance

Groundwater Monitoring Issues (cont'd)

- Saturated Groundwater Quality Monitoring
 - Monitoring of Typical Production Wells Near Pollutant Source
 - Not Reliable for Detecting Pollution Before Widespread Pollution Occurs
 - Well Location & Screen Length Issues
 - Need Specific Monitoring Wells Established to Sample Just Below Water Table Just Up- and Down-gradient of Pollutant Source
 - Considerable Seasonal Effects of Variable Water-Table Depth

Dairy and CAFO Wastes

- Wastewater & Manure Lagoons Using Clay &/or Plastic Sheeting (including single-composite liners) Not Reliable for Protection of Groundwater from Pollution by Nitrate & Salts
 - Liners Will Deteriorate & Leak
 - Cannot Reliably Monitor Groundwater for Initial Liner Leakage
 - Should Use Double-Composite Liners with Leak Detection System between the Composite Liners to Detect Upper Composite Liner Failure

Pollution of Groundwaters by Salts

- Pollution by Salinity/Salts
 - One of Most Significant Groundwater Pollution Situations in California
- Caused by Many Sources, Including
 - Irrigated Agriculture
 - Domestic Wastewaters
 - Some Industrial Wastewaters
- CVRWQCB Developing “Salinity Policy” to Work toward Controlling Groundwater Pollution by Salts

<http://www.waterboards.ca.gov/centralvalley/cv-salts/index.html>

Vadose Zone Transport of Pollutants

- Cannot Reliably Predict Rate of Pollution of the Saturated Part of the Groundwater Aquifer Using Vadose Zone (Unsaturated) Transport Models That Do Not Adequately Consider
 - Preferential Pathways and
 - Wetted-Front Transport of Pollutants
- Average Annual Moisture Content of Vadose Zone Not Reliable for Estimating Rate of Transport through Vadose Zone - Unfortunately Allowed by Regulatory Agencies

Municipal Solid Waste Landfilling

- In 1984 SWRCB Adopted Chapter 15 which Required that Landfilling of Municipal Solid Wastes (MSW) Occur in Landfills that Prevent Pollution of Groundwaters for as Long as the Wastes in the Landfill Will Be a Threat
 - In a Dry Tomb Landfill (plastic sheeting and clay-lined & covered) the Wastes Will Be a Threat Forever

Inadequate Regulation of MSW Landfilling

- Essentially All MSW Landfills Developed Since 1984 (Including Those Being Develop Today)
 - Will Pollute Groundwaters with Landfill Leachate
 - Rendering the Groundwater Unusable for Domestic Water Supply & Many Other Purposes
- At some Landfill Locations
 - Groundwaters Will Be Polluted by Hazardous and Otherwise Deleterious Chemicals for a Mile or so from the Landfill

Inadequate MSW Landfilling

- Regional Boards' Staff & Boards and SWRCB Failed to Properly Implement Chapter 15 (Now Title 27) MSW Landfilling Regulations to Protect Groundwaters from Pollution by Landfill Leachate
 - Regional Board Staffs Allowed Use of 1-ft-Thick Clay Liner with Permeability of 1×10^{-6} cm/sec at Landfill Sites Lacking Natural Protection of Groundwater
 - Did Not Implement Chapter 15 Requirements of a Site-Specific Evaluation of Needed Liner Characteristics
 - Staff Ignored Darcy's Law
 - Such a Liner Will Fail in Less Than a Year
 - SWAT Results Demonstrated that Landfills with This Liner Polluted Groundwaters as Predicted by Darcy's Law

Inadequate MSW Landfilling (cont)

- Minimum-Design US EPA Subtitle D Landfills
 - Single-Composite Liner
 - Plastic Sheeting & Compacted Clay
 - Will Eventually Allow Groundwater Pollution When Liners Fail to Prevent Leakage
 - Flawed Technology for MSW Landfilling
 - Will Not Protect Groundwaters from Pollution for as Long as the Wastes in a Dry Tomb Landfill Will Be a Threat - i.e., Forever

Recommended Landfilling Approach

- Landfill Only Non-Recyclable Wastes
- Use Double-Composite-Lined Landfill Having Leak Detection Layer between the Two Liners
- For Postclosure, All Landfill Owners
 - Post a Trust Fund & Adequate Insurance of Sufficient Magnitude to Monitor/Maintain Landfill Containment System for as Long as the Wastes in the Landfill Will Be a Threat – Forever
 - Assured Funding Needed to Remediate Eventual Pollution of Groundwaters
 - *ad infinitum* Funding Especially Important for Privately Owned Landfills

Alternative Approach Needed for Landfilling

- US Congress Made Significant Error in Dictating Use of “Dry Tomb” Landfills for Solid Waste Management
 - Liner Systems Allowed Will Eventually Fail
 - Groundwater Pollution Likely to Occur at Many Dry Tomb Landfills
 - Monitoring Likely Inadequate to Detect Failure of Liner System & Initial Groundwater Pollution
- Flawed Nature of US EPA Subtitle D Landfilling Technology Beginning to be Understood
 - See, Lee, G. F. and Jones-Lee, A., “Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste,” Report of G. Fred Lee & Associates, El Macero, CA, December (2004). Updated March (2006).

<http://www.members.aol.com/apple27298/SubtitleDFlawedTechnPap.pdf>

Bioreactor Landfills

- Do Not Try to Keep Landfilled Wastes Dry Forever
 - A Major Flaw of “Dry Tomb” Approach
- Develop Landfills That Treat the Wastes to Produce Non-Polluting Residues
- Key to Producing Non-Polluting Residues for Landfilling:
 - Add Moisture to Ferment & Leach the Wastes
 - Produce Landfill Gas
 - Leach the Leachable Components from Fermented Wastes

Bioreactor Landfills (cont'd)

- Conventional Bioreactor Landfills
 - Recycle Landfill Leachate Back into Landfill
 - Not Reliable for Fermentation & Leaching of Landfilled Wastes to Rapidly Produce Non-Polluting Residue
 - Plastic-Bagged Wastes Will Not Be Adequately Exposed to Water Added to Landfill
 - Single-Composite Liners Can Fail to Prevent Pollution of Groundwater
 - Leakage May Not be Detected until Widespread Off-Site Pollution Has Occurred

Bioreactor Landfills (cont'd)

- Adaptations Needed for More Reliable Protection of Groundwater Quality:
 - Shred the Wastes
 - Conduct Fermentation & Leaching of MSW in Double-Composite-Lined Landfill
 - Practice Leachate Recycle While There Is Active Landfill Gas Production
 - After LF Gas Production Ceases, Wash Landfilled Wastes with Clean Water, Without Further Leachate Recycle

Other Waste Landfilling Issues

- Avoid Siting Landfills in Fractured Rock/Clay and Complex Aquifer Systems
 - Such Systems Cannot Be Reliably Monitored for Pollution by Landfill Leachate
- Construction & Demolition Wastes Are Not Inert
 - Significant Potential to Pollute Groundwater
 - Should Be Landfilled in Double-Composite-Lined Landfills

Groundwater Pollution of Surface Waters

- Land Disposal of Wastewaters and Wastes Can Cause Shallow Groundwater Pollution that Pollutes Nearby Surface Waters
 - Occurs in the Central Valley SJR Watershed where some Municipalities are Disposing of POTW Effluents by Spreading on Land where Shallow Groundwaters Discharge to Nearby Surface Waters
 - Also Occurs Near Landfills with High Groundwater Table
- All Land Disposal of Wastes Should Include Detailed Monitoring of Shallow Groundwaters to Determine if Surface Water Pollution is Occurring

Enhanced Groundwater Recharge

- Enhanced Groundwater Recharge Needed for Storage of Surplus Surface Waters in Aquifers for Withdrawal during Droughts
- Must Be Done Carefully to Avoid Pollution of Groundwater & Damage to Quality of Aquifer for Storage of Water for Future Use
- Aquifer Storage & Recovery (ASR) of Treated Domestic Water Supply Waters Can Pollute an Aquifer with THMs, Organic Carbon, Other Constituents

Stormwater Infiltration

- Urban Stormwater & Agricultural Runoff Typically Contain Chemicals that Can Cause Groundwater Pollution
 - Use of Urban Stormwater Infiltration as a “BMP” to Control Surface-Water Impacts of Chemicals Can Lead to Groundwater Pollution
 - All Stormwater Infiltration Should Be Accompanied by Detailed Groundwater Monitoring to Detect Groundwater Pollution before Widespread Pollution Occurs

Shallow Injection Wells

- Current US EPA Regulations Governing Shallow (Class V) Injection Wells Not Adequate to Protect Groundwaters from Pollution by Chemicals in Injected Waters
 - Need to Greatly Restrict Use of Shallow Injection Wells
 - Any Use Should Be Accompanied by Detailed Groundwater Monitoring

Deep Well Injection

- Deep Well Injection of Wastewaters Can Cause Groundwater Pollution
- Current Regulatory Approaches Provide Somewhat Better Protection of Groundwater from Near-Term Pollution by the Injected Wastewaters
- Potential Long-Term Problems
 - Injected Wastewaters Can Pollute Groundwaters Once Protective Character of Injection Containment System Loses Integrity

Dust Suppressants

- Dust Suppressants Used to Control Dust Emissions from Properties & Roads – Some Dust Suppressants are Wastes
 - Use Should Be Accompanied by Evaluation Studies & Monitoring to Determine Potential for Pollution of Surface Water and Groundwater

Natural Attenuation

- Controlling Spread of Pollution from a Source by “Natural Attenuation”
- Should Be Used Only When
 - Source Has Been Removed, and
 - There is Detailed, Ongoing Monitoring of Full Range of Potential Pollutants & Their Degradation/Transformation Products
 - Only Considering BTX as Pollutants from Leaking Gasoline Storage Tanks Ignored MTBE

Unrecognized Pollutants

- Current Approach for Evaluating Potential for a Waste Source or Activity to Cause Groundwater Pollution
 - Based on Grossly Limited Set of Pollution Parameters Compared to Vast Array of Potential Pollutants in Many Complex Waste Sources
 - Only 100 or so Chemicals Included in Groundwater Quality/Pollution Evaluation
 - There Are Thousands of Unmonitored & Unregulated Chemicals in Use that Can Cause Groundwater Pollution
 - Example: Perchlorate

Typical Environmental Sample Analysis

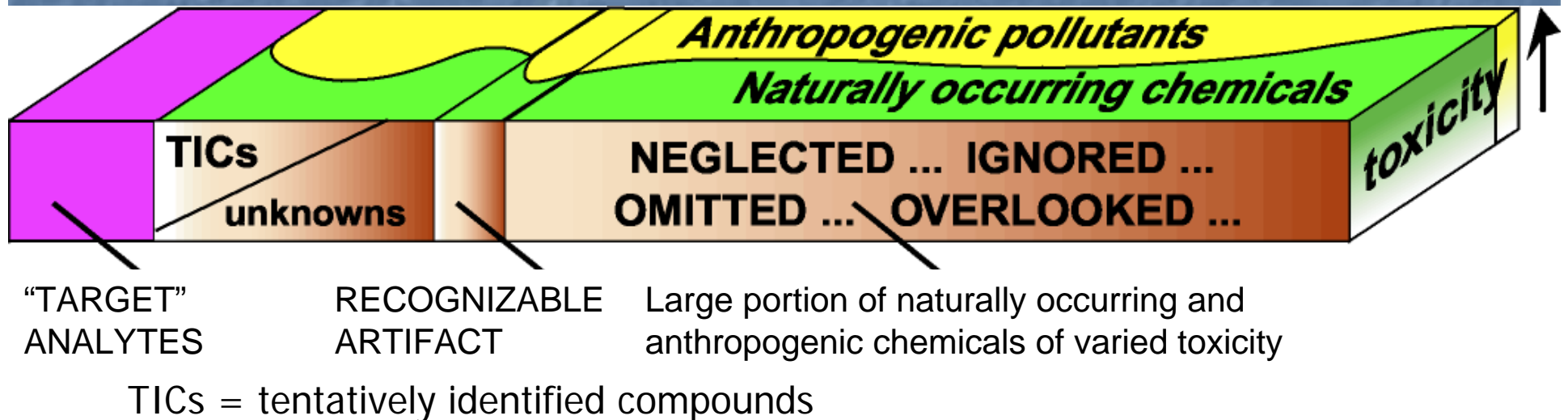


Figure from: Daughton, C. C., "The Critical Role of Analytical Chemistry," July (2002)
<http://www.epa.gov/nerlesd1/chemistry/pharma/critical.htm>

Sealing of Wells

- Current Approach of “Sealing” Wells between Aquifers & from Surface Pollution Using Bentonite Clay or Cement
 - Can Be Effective Initially
 - In Long Term, Can Fail Due to Cracking of Seals Owing to Ion Exchange Reaction of Calcium with Sodium in the Bentonite
 - Similar Problems Occur with Cracks Developing in Cement-Based Seals

Chlorinated Solvents

- Examples: PCE, TCE, Chloroform
 - Transformation Product Vinyl Chloride
- Common, Widespread, Highly Hazardous Groundwater Pollutants
- Highly Persistent in Groundwaters
- Limited Attenuation in Aquifers
- Regulated as Carcinogens
 - TCE is One of the Most Common Groundwater Pollutants
 - Reduction of MCL being Considered

Underground and Above-Ground Leaking Tanks and Spills

- Many Underground Storage Tanks, Such as Used for Storage of Gasoline & Other Fuels, Have Developed Leaks
 - Caused Pollution of Groundwater by Stored Product
- Current Regulations
 - Can Be Effective in Reducing the Pollution of Groundwaters by Leaking Tanks
 - Problems Remain with Vapor Leaks from Tanks in the Underground Vapor Lines

Protection of All Aspects of Groundwater Quality

- Problem with Some Regulatory Agencies
 - Focus Groundwater Pollution Control Programs on Priority Pollutants While Ignoring Pollution by Other Chemicals that
 - Are Not Considered Highly “Hazardous” but
 - Can Cause a Groundwater to be Unusable for Domestic Supply & Other Purposes
- All Groundwater Pollution Evaluation/Control Programs Should Focus on All Aspects of Impairment of Use of Groundwaters, Including Tastes & Odors
 - Required by Porter-Cologne

Importance of Protecting Groundwater Quality

- Significant Difference in Pollution of Surface Water & Groundwater
 - Surface Waters
 - Usually Rapid Dilution
 - Photo-Decay & Greater Biological Activity
 - Rapid Recovery When Input of Pollutant Controlled
 - Groundwater
 - Limited Dilution
 - Less Bio-Activity
 - Once Polluted, Polluted Aquifer Area Likely Not Usable Again for Domestic Water Supply

Importance of Protecting Groundwater Quality (cont'd)

- Regulatory Agencies
 - Typically Enforce Regulations in Surface Water Pollution Situations
 - Commonly Fail to Enforce Regulations for Groundwater Quality Protection
 - Should Place Greater Emphasis on Protecting Groundwaters

Water Utilities' Role in Groundwater Quality Protection

- Groundwater Important Source of Domestic Water Supply
 - Importance Will Increase in Future with Conjunctive Use
- Water Utilities & Other Groundwater Users Should Become Active Participants in Groundwater Quality Protection
 - Participate in Regional Board Hearings on Permitting of Land Surface Activities That Could Lead to Groundwater Pollution
 - Ensure Adequate Monitoring to Detect Incipient Groundwater Pollution
- Work to Develop Comprehensive Groundwater Quality Monitoring Network in the State

Further Information
Consult Website of
Drs. G. Fred Lee and Anne Jones-Lee



<http://www.gfredlee.com>